DOCUMENT RESUME

ED 300 140 PS 017 638

AUTHOR Rieben, Laurence; And Others
TITLE Cognitive Development and Individual Differences: On the Necessity of a Minimally Structuralist Approach of Development for Educational Sciences.
PUB DATE 87
NOTE 27p.
PUB TYPE Information Analyses (070)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Development; *Cognitive Structures; *Developmental Stages; Educational Research; *Individual Development; *Individual Differences; Models; Piagetian Theory; *Research Methodology

ABSTRACT

The application of Piagetian theory to educational practices encounters a series of major difficulties. The main focus of this paper is on the notion of general stages, which has been under attack in numerous studies. Organized in four parts, the paper: (1) discusses the problem of the existence of general stages and of a developmental unidimensionality; (2) argues that, in order to account for the variance of behaviors, general sources of influence should be dissociated or disentangled from specific sources, and concludes that developmental and differential approaches are necessary; (3) hypothesizes links between this approach and other theoretical models that deal with cognitive development or individual differences; and (4) discusses educational implications of the various models. A research program that led to the hypothesis of different forms of development is described in the second section. Cited are 62 references. (RH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED300140

Cognitive development and individual differences: On the necessity of a minimally structuralist approach of development for educational sciences.

Laurence Rieben, Anik de Ribaupierre,
Faculté de Psychologie et des Sciences de l'Education, Genève

Jacques Lautrey
Laboratoire de Psychologie Différentielle, Université de Paris V

Correspondence to:
Laurence Rieben
Faculté de Psychologie et des Sciences de l'Education
Uni II
1211 Geneva 4
Switzerland

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Laurence Rieben
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

PS 017638

BEST COPY AVAILABLE

Cognitive development and individual différences: On the necessity of a minimally structuralist approach of development for educational sciences

Laurence Rieben, Anik de Ribaupierre & Jacques Lautrey

Two general aspects of the Piagetian theory have particularly retained the interest of educators: its constructivist perspective, which has emphasized the active role taken by children in the construction of their knowledge base and led to the development of active methods of teaching, and its structuralist facet, with the notion of stage. Constructivist approaches to education have strongly recommended to aim at long-term development, as opposed to the teaching of specific skills. Accordingly, it appeared important either to accelerate the transition from one stage to the next, or to match the notions to be taught to stage characteristics.

However, resorting to the Piagetian theory in the field of education encounters a series of major difficulties. The first problem, constituting the main focus of this paper, lies in the notion of general stages, which has been under attack in numerous studies. If overall structures ("structures d'ensemble") do exist, one can nevertheless wonder whether their achievement should indeed represent educational objectives; they are probably too long-term objectives to be useful and also too general to be assessed. It is also necessary to understand how their construction could be accelerated through learning procedures. If these criticisms are to be taken seriously, one then wonders whether a structuralist perspective should be totally rejected or to what extent it could be accommodated to fit educational needs. The present paper is organised in four parts. First the problem of the existence of general stages and of a developmental unidimensionality is discussed. Second it is argued that, in order to account for the variance of behaviors, general sources of influence should be dissociated or disentangled from specific sources; accordingly, the necessity to integrate both a developmental approach and a differential approach is stressed. As an illustration, a research program that led to the hypothesis of different forms of development is presented. Thirdly, links are hypothesized between this approach and other theoretical models, in particular anglo-saxon ones, that deal with cognitive development or/and with individual differences. Finally, educational implications of these different models are discussed.

The problem of general stages

According to the Piagetian model, cognitive development consists in a construction of structures that emerge in an invariant order and can be generalised to all domains of knowledge as soon as they are achieved. Development is therefore considered unidimensional: its form is supposed to be the same for all subjects, and the only individual differences allowed for are differences in the speed of development. On the basis of a purely structuralist approach, one would expect that all subjects behave at a same structural level across all domains. However, Piaget himself introduced the concept of horizontal decalage to account for asynchronisms between notions supposed to rely on a same overall structure. This concept presents two major flaws: it can only account for situational variability (in terms of resistances that objects oppose to the subjects' structuring activity-- e.g., Piaget, 1968) and it can only be used a posteriori since task analyses of situational characteristics are not an integral part of the theoretical model.

Most studies that attempted to test the Piagetian theory, or replicate Piagetian findings, underlined the frequency of such horizontal decalages and therefore questioned two related major features of the model: the generality of stages and the unidimensionality of development. Morevoer, since the sixties, studies that focused on the development of different notions in same children pointed to weak correlations (e.g., Dodwell, 1960; Lunzer, 1960; Tuddenham, 1971). Provided that only the intensity of relationships between tasks is studied, such types of asynchronism can still be interpreted within a Piagetian framework: they constitute decalages in the same direction for all subjects, and thus do not challenge the undimensional facet of the model. Subsequently, Longeot's studies (Longeot, 1969, 1978) for instance contributed to further comprehension of intra-individual variability of operational development, by assuming the possibility of different forms of development, at least during certain phases. Longeot studied essentially the transition from concrete operational stage to formal operational stage, and suggested to dissociate a phase of preparation from a phase of achievement in the construction of operations. With respect to the two fundamental structures postulated by Piaget as underlying the stage of formal operations, certain subjects would first master the INRC group and then the combinatorial structure, while others would present an inverse pattern. This means hypothesizing the existence of different paths for different subjects, at least during the phase of preparation. According to Longeot, these paths

converge during the phase of achievement; this point is still open, however. One of the main contribution of Longeot's work consists of the distinction suggested between collective horizontal decalages and individual horizontal decalages. Collective decalages are in the same direction for all subjects, like in the prototypical decalage in conservation tasks: conservation of substance precedes conservation of weight that in turn precedes conservation of volume, for all subjects. By contrast, individual decalages are in different directions for different subjects: for instance, some subjects could master conservation of substance before being able to seriate rods, while others could present an inverse pattern. Such decalages represent a much more serious challenge to the postulate of an overall structure defining general developmental stages. If Longeot well documented the presence of such decalages during the preparatory phase of the formal stage (stage that remains problematic anyway- see for instance Neimark, 1981; de Ribaupierre, 1975), one can wonder whether they subsist beyond this period and also whether they can be found earlier in development, during stages that appear better validated, such as the concrete operational stage or the sensori-motor stage. Thus the study of decalages corresponds to a study of individual variability. Such an approach is now going to be illustrated through the program of research that we have been conducting for a number of years.

Structural aspects and individual differences

The problems that were just mentioned, in particular the numerous asynchronisms demonstrated between different notions supposed to be synchroneous, have often led researchers to claim that there are no invariances across situations (e.g., Brainerd, 1978). We want to argue that the baby should not be thrown with the bath water, and to defend the necessity of a structuralist approach while clarifying at least two points. Indeed, if the Piagetian structures as they are defined and formalised in the theory are probably not to be retained, it is not sufficient ground to totally reject a structuralist approach. It proves useful to distinguish between a structure and a structuralist approach: in the first case, one attempts, as Piaget did, to define and/or formalise relations or rules of composition between elements, independently from content; by contrast, a structuralist approach can be defined simply as a search for invariances across types of situations and types of subjects, while these invariances themselves need not necessarily be formalised structures. This is the reason why we refer to a minimally structuralist approach. A second point that we want to stress is that, even if general

developmental invariances can be hypothesized, they are in no way sufficient to account for the variability of performance. They should be combined with sources of situational and individual variability that are just as fundamental. This is a second reason to adopt a minimally structuralist perspective.

Our main postulate is that subjects' performances are to be understood as multidetermined or overdetermined, in the sense that they are under the combined influence of several sources of variation, both general and specific. The general sources can be seen to consist in a general developmental factor, on the subjects' side, and in a general factor of complexity, on the situational side. The specific sources of variance consist of situational differences and of different processing modes in individuals interacting with the situational variables. Our hypothesis, following the proposal of the french differentialist Reuchlin (e.g., 1978) is that such modes are present in each individual, almost like different options (or vicarious processes) available for treating information; with time, or experience, individuals could come to privilege one over the other. Therefore, in terms of individual differences, subjects could process differently a same problem while reaching a same solution; such processes would not be independent from situational characteristics either. In order to tease out the influence of these general and specific sources of variation on the subjects' performance, both environmental or situational variables on the one hand, and individual or organismic variables on the other hand have to be considered jointly, together with their interactions. It also proves necessary to see the same subjects across different types of situations, whereas most structuralist approaches, obviously including Piaget's, have built general laws by comparing different groups of children. To neglect subjects-situations interactions can lead to a paradox, such as describing subjects' information-processing modes on the sole basis of situational characteristics; for instance the distinction introduced by Piaget between logico-mathematical and infra-logical operations[1] relies only on the scale of the object structured by these operations. This neglect can also end in abusive generalisations: the observation of performances in mental imagery tasks and in perception tasks led Piaget to postulate that figurative aspects of knowledge are subordinated to operative aspects (e.g., Piaget & Inhelder, 1966; see also Note 5); such a relationship could indeed be valid for certain types of subjects, but not all: those which tend to process infra-logical or mental imagery tasks just like

logico-mathematical situations, and thus to privilege operative aspects. This problem will be discussed again later.

The program of research that will be briefly described represents such an attempt to combine general structuralist aspects with more specific aspects, by resorting to both a developmental and a differentialist (individual-differences) approach. Its objective is to assess not only the magnitude but more importantly the form of intra- and inter-individual variability of operational development, in order to determine which laws, both developmental and differential, govern it. Accordingly, in order to determine the degree of synchronism, it proves necessary to establish structural correspondences between performances in different domains, and therefore to define invariances across situations; note that since development is considered multidimensional, the model predicts that strict synchronism will not necessarily be obtained.

To this purpose, we used a set of eight operational tasks, somewhat modified from the original Piagetian tasks, and administered it to children aged 6 to 12. These tasks are representative of different notional domains: logico-mathematics, physics and geometry, representation of space and mental imagery. Details about the tasks can be found elsewhere (Lautrey, de Ribaupierre & Rieben, 1985; de Ribaupierre, Rieben & Lautrey, 1985; Rieben, de Ribaupierre & Lautrey, 1983).

The definition of structural correspondences between levels of performance, including intermediate levels, is a prerequisite to the distinction of different types of decalages, and to the study of individual variability; it therefore proved necessary to devise a system that allows for comparisons across tasks. Indeed the Piagetian framework does not provide the possibility of such comparisons, in particular with respect to intermediate behaviors[2]. The system of analysis that we developed can be considered as structuralist-rationalist (e.g., Rieben, de Ribaupierre & Lautrey, 1986), because it is defined across tasks and relies on rational-types of task analyses. It is directed toward an analysis of both the tasks' complexity and the subjects' performances.

We therefore suggested the concept of <u>dimension of transformation</u>. Indeed, all Piagetian-type tasks suppose, on the subject's part, activities of transformation, whether actual or represented; a dimension of transformation can be defined as a transformational action or representation scheme. Our task analyses led us to postulate that, depending on the items, the number of required such dimensions of transformation varied from one to three; the subjects' performances

(whether judgments, productions and/or verbal arguments) can be analysed as a function of the emergence and growing articulation[3] of dimensions, which led us to describe six ordered levels of performance (see Rieben et al, 1983):

1) No dimension of transformation; at this first level, subjects apparently do not impose any transformation on the input;
2) emergence of a first dimension of transformation;
3) emergence of a second dimension of transformation, but not articulated with the first one, i.e., disjunctive;
4) articulation of the two dimensions;
5) emergence of a third dimension where it is relevant, but like in level 3 not yet articulated with the two preceding ones;
6) articulation of the three dimensions.

The notion of dimension of transformation can be explicited further with the example of a task, the Folding of Lines task. In this task, subjects are presented with geometrical figures made up of different colored lines drawn on tracing paper (see Figure 1); they are asked to anticipate, and draw with colored pens, the figure obtained when the sheet of paper is folded in half, the lower part being placed on top of the upper part. They first have to draw the folded sheet. The task consists of five items, including an example.

Insert Figure 1 about here

The dimensions of transformation hypothesized to be necessary for the solution of the task are the following. Dimension 1 consists in a transformation of the relationship above-below into a relationship under-over; first the subject has to understand that the sheet of paper becomes smaller and that the lower part (i.e., the elements below the fold clearly indicated on the sheet of paper) will cover the upper one. The transformation corresponding to Dimension 2 consists in a rotation, which means that the relative positions of the elements of the lower part will be inverted. This requires defining an intra-figure axis of rotation, that should be the fold itself or the line drawn on it, but children can and frequently do adopt another axis of rotation, such as the diagonal in Item 4 for instance. The transformation subsumed in Dimension 3 consists in taking into account the left-right orientation, that is, understand that the rotation preserves the left-right position of the lower elements. This dimension is not necessary for all items; for instance, in Item 1,

children could use only the first two dimensions.

Insert Figure 2 about here

The children's productions can be analysed according to the presence and degree of articulation of these three dimensions, which leads to the definition of six levels of performance. Figure 2 gives examples of performances representative of each level for each item. In Level 1 (no dimension), the subjects' drawing corresponds, for the observer, to a copy of the non-folded model. Children at Level 2 (one dimension) understand that by being folded the sheet of paper becomes smaller and that only one part of the figure will be visible, most often the lower part (but children sometimes draw the upper part). No transformation is yet performed on this part of the figure. At Level 3 (two non-articulated dimensions), children define an intra-figure axis of rotation and understand that the bringing up of the lower part to the upper part leads to an inversion in the relative position of the elements. However, this second dimension is still treated independently from the first one; this results in a mismatch between the axis of rotation and the fold, and a misplacement of the figure relative to the sheet of paper. At Level 4 where the first two dimensions are articulated, the two axes (rotation and fold) generally coincide (although not necessarily, for instance in Item 4), with the result of a correct location in the sheet of paper. These two dimensions are sufficient to solve Item 1. At Level 5 (three non-articulated dimensions), children start to understand that the rotation preserves the left-right relative position and that, as a result, an oblique line will be transformed into a "V". However, the three dimensions are still used in a partially disjunctive way, with the consequence that either the drawing is, like in Level 3, placed in the middle of the sheet, or the dimensions are not articulated for each element. At Level 6, the three dimensions are articulated, which does not necessarily imply complete success on the task yet.

Similar analyses were conducted on the seven other tasks used in the set; it proved possible to define, like for Folding of Lines, from one to three dimensions of transformation, and therefore from one to six levels. To stress the point, it is obviously not the content of the dimension (e.g., rotation in the case of Folding of Lines) that constitutes the structural invariant across situations, but the number of dimensions used and their degree of articulation. This system certainly presents several

limits, some of which are intrinsic to any structuralist approach. First, it remains relatively molar; this level of generality is necessary for a comparison across so radically different tasks. It is also essentially qualitative, even if it is more quantitative than the Piagetian system; consequently, it remains discrete and cannot account for quantitative features, i.e., for a quantitative increase in the complexity of tasks and/or performances. It is thus not possible, within the system, to define different levels corresponding to various degrees in the emergence of a dimension, even though such an ordering may be relatively obvious in items or performances; for instance, it can only take into account the fact that one or several dimensions, articulated or not, are used, and not the number of elements to which these dimensions apply. A third limit, characteristic of any structuralist approach, is due to its atemporal characteristic: it does not provide the possibility for a sequential or step-by-step unfolding of subjects' processing; therefore, instances in which the to-be-articulated dimensions have to be applied jointly cannot be distinguished from those in which they may apply sequentially[4]. In consequence, the complexity of tasks all of which call for the same number of dimensions might vary. Given these fundamental limits, the system of analysis is not sufficient to entirely control the general sources of variance. Note that, even if these limits could be remediated via combination of qualitative and quantitative analyses (e.g., Case, 1985; Pascual-Leone, 1980), strict synchronism would not be predicted, since we do not adhere to an unidimensional and purely structuralist perspective. It is nevertheless argued that the structural analysis represents an important prerequisite, in order to control for developmental and complexity aspects and to get a clearer image of individual variables, which then should no longer be embedded within developmental ones.

Empirical results will only be mentioned briefly. For more details, the reader is referred to other publications (e.g., Lautrey, de Ribaupierre & Rieben, 1987; de Ribaupierre et al, 1985; Rieben et al, 1983, 1986). Between-tasks relationships were investigated both from the standpoint of their intensity, through Kendall's Tau coefficients of correlation and, more importantly, in terms of their form by means of the Del index developed by Hildebrand et al (Froman & Hubert, 1980; Hildebrand, Laing & Rosenthal 1977). This was used to test the predictibility of three models: synchronism between two tasks A and B, collective decalage in favour of Task A, collective decalage in favour of Task B. The presence of

individual decalages (for a definition of collective and individual decalages, see above) could be inferred from these three models: indeed, if none of them proves significantly more predictive, this means that there are as many subjects for whom task A is easier than task B as subjects presenting the inverse pattern. In the data, the manifestation of a general source of variability was attested by the magnitude of the correlations (the Tau coefficients were all significant, although never very high-- around the 40's) and by a better adequation of the model of synchronism in approximately half the pairs (15 cases over a total of 28). Collective decalages were also relatively frequent (9 cases); they can be imputed to both a situational source of variability and a general source of complexity, since they apply to all subjects. Individual decalages were, however, found in 4 cases; they can be interpreted as arising out of individual sources of variability. It is interesting to notice that they all occurred in pairs contrasting logico-mathematical with infra-logical tasks.

These results are all the more interesting because they link up with those obtained through a different type of approach that we used previously; we labelled that approach empirical by contrast with the present rationalist one (Rieben et al, 1986) because it only relied on passes/failures on items and on the empirically demonstrated within-task order (no structural correspondences were a priori established across tasks). Within this empirical approach, the same analyses were conducted in order to determine the intensity and the form of relationships, with similar overall results (Lautrey et al, 1985, 1987; de Ribaupierre et al, 1985). Moreover, it was possible to proceed to analyses of correspondences (sort of factor analyses at a nominal scale level-- Benzecri, 1973) that allow for a grouping of items together with subjects. A general factor emerged, which can be interpreted both as a developmental factor on the subjects' level and as a complexity factor on the items' level. Once this general variance controlled for, two group factors appeared, one of which precisely opposed infra-logical tasks to logico-mathematical tasks; this implies that the solution of these two types of tasks is relatively independent for different subjects (Lautrey, de Ribaupierre & Rieben, 1986, 1987).

The presence of individual decalages and of group factors can thus be taken to support the hypothesis according to which development is not unidimensional and there exist different modes of processing, related to the distinction between logico-mathematical and infra-logical tasks.

Indeed, if some subjects solve relatively difficult logico-mathematical items while still failing relatively easy infra-logical items, and if some subjects present just the opposite pattern, this probably means that these two types of subjects rely on different processes for treating the same information. Thus, the differences obtained between the types of situations, and the fact that they can be analysed as being discrete (logico-mathematical) versus continuous (infra-logical) led us to infer the existence of at least two information-processing modes: a discrete, analytical or digital mode and a continuous, more global or analogical mode. In conformity with Reuchlin's hypothesis of vicarious processes (Ohlmann, 1985; Reuchlin, 1978; de Ribaupierre, in press), these two modes should be conceived of as coexisting in each subject, being optional one vis-à-vis the other within an individual, at least at some point in development. They should also be considered linked to situations, that is, situational characteristics would call for differential processing: the digital mode seems most appropriate for treating discrete problems such as logico-mathematical tasks, while the analogical mode would seem most appropriate for treating continuous problems such as infra-logical situations. Optimal functioning appears to depend on an interaction between type of situation and mode of processing, and therefore on a flexible usage of each mode. However, as shown in Figure 3, this flexibility might yield individual differences, since subjects could develop, probably in a cumulative manner, a preference for one mode over the other. This would have various empirical consequences. Synchronism could be obtained when the modes are equivalent in terms of their accessibility and when subjects "know" when to apply each. The preference for a digital mode and its application to both types of situations could lead to a decalage in favour of logico-mathematical operations, since a discrete treatment of infra-logical situations would first require a breaking-up of the parts[5]; conversely, the preference for an analogical mode would lead to a decalage in favour of the infra-logical. Finally, there could be subjects who cannot "decide" which mode is optimal given a particular situation, although for them the two modes would also be equally accessible; they would then differ from the first type of synchroneous subjects in "strategic" usage of the modes. The empirical consequence is not clear (indicated by a quotation mark in the Figure), but it could well be that these subjects finally present a delayed synchroneous pattern in each type of situation.

Insert Figure 3 about here

Comparison with other theoretical models

It is worth mentioning the parallel that can be drawn between our approach and models currently proposed in the literature, in particular anglo-saxon. Such a comparison can be made at the two levels mentioned in this paper: the general-structuralist and the more specific individual/situational levels. After a period of strong emphasis on the autonomy and specificity of different notional domains (which itself succeeded a period of interest in general structures), it is indeed encouraging to note a growing resurge of interest in the search for relatively general structures even though they are not formalised, particularly in the field of developmental psychology (for instance, Case, 1985; Fischer, 1980; Fischer & Silvern, 1985; Pascual-Leone, 1976, 1980; Siegler, 1983, 1984); likewise, in approaches linking experimental psychology with individual-differences approach, there is a recent trend to look for general invariances across situations, such as Sternberg's metacomponents (Sternberg, 1980, 1983) or metacognitivist control processes (e.g., Brown, Bransford, Ferrara & Campione, 1983; Snow & Yalow, 1982).

As an example, it is worth stressing the similarity, that we only recently noticed, between our approach and Siegler's (e.g., Siegler, 1981, 1983; Siegler & Klahr, 1982), which defines Rules necessary for the solution of a problem and predicts when the adoption of a given Rule will lead to failures. This represents, like our analyses in terms of dimensions of transformation, an attempt to classify all the observed performances, including intermediate ones, in a hierarchical system which in turn allows for tasks comparisons. For instance, the use of Rule 1 characterizes the younger subjects who, in the Balance task, rely on only one dimension, just as the performances of our Level 2 subjects result from the emergence of a single dimension of transformation. Siegler's Rule 2 subjects take into account one variable (like the weight on each side) and, if it is invariant, they consider a second one (distance); this corresponds to our Level 3 where two dimensions of transformation are taken into consideration, but are not yet articulated. The comparison can be extended to the higher levels. However, the parallel is limited to the task analyses, and does not extend to the general approach. Whereas our research programme essentially focuses on the problem of horizontal

decalages and individual differences, an additional asset of Siegler's work consists in the adoption of a learning approach, i.e., in the study of the transition from one Rule to the next. Our system also attempts to distinguish different levels of intermediate behaviors while Siegler's only predicts passes or failures given the adoption of a Rule.

The search for structural invariants across situations is even clearer in Case's work (e.g., 1978, 1985), whose objective is more ambitious, since he attempts to elaborate a general cognitive theory from birth to adulthood. For each stage defined, Case stresses both the emergence of new types of control structures (dimensional control structures for the age range that the present paper focuses on) and their growing degree of coordination (operational, bifocal and elaborated); that is, his model, like Pascual-Leone's (e.g., 1980), attempts to embody both qualitative and quantitative aspects of development. Further, some of his work (Case, 1985; Case, Marini, McKeough, Dennis & Goldberg, 1986), tackles directly the problem of synchronism across situations. He stresses the fact that, in order to observe invariances, it is necessary to study relatively simple situations (see also de Ribaupierre & Pascual-Leone, 1984), which is obviously not the case of Piagetian-type tasks. Even so, individual differences emerge (Case et al, 1986) which seem to be imputed to the subjects' preliminary experience and are apparently considered as mere variations around general norms. By contrast, our interest is not so much focused on the magnitude of this variability, as on its form.

With respect to the organisation of different forms of development, that is, of the continous/analogical versus discrete/digital dimensions that we attempt to link both with situational and individual differences, the literature seems to abound in suggestions for such dichotomies. However, the distinctions have more often originated in strictly experimental and/or developmental psychology than in differential psychology. Without being exhaustive, the hypothesis of two modes of processing obviously ties in with models postulating a relative specificity of mental imagery processing, in particular Paivio's or Shepard's (e.g., Denis, 1979; Paivio, 1971; Shepard & Cooper, 1982). From a developmental perspective, similarities can be mentioned with Bruner's distinction between ikonic and symbolic thinking (Bruner, 1964; Bruner, Greenfield & Olver, 1966; Galifret-Granjon, 1981), on the one hand, and with the distinction between holistic and analytic modes of processing adopted by different information-processing researchers (e.g., Kemler & Smith, 1978; Kemler Nelson & Smith, in press), on the other hand. The

emphasis here is often developmental: the dichotomy is linked to periods of development, since the child is described as shifting from an ikonic to a symbolic mode or from holistic to analytic. Even if the models do not postulate a complete substitution of one mode by the other, the transition is often characterised in terms of a progression. It is less common to consider the two modes to be vicarious or optional one vis-à-vis the other. Some of the work dealing with the holistic-analytic dimension attempted to demonstrate the equivalence of the two types, but had to conclude to the superiority of the analytic processing (Kemler Nelson & Smith, in press). Our distinction can also be likened, although less closely, to that introduced by Piaget (e.g., 1976) in his later work between procedural and presentative schemes, or even the distinction between procedural and declarative types of knowledge (e.g., Anderson, 1983), in that an analogical mode of processing, just like procedural schemes or knowledge (knowing how), embodies more spatio-temporal features than a digital or presentative mode (knowing that). Here, however, different types of representation are defined as a function of situations and/or of the goals that the subjects want to reach (understanding versus succeeding in the case of the Piagetian distinction), without being considered amenable to individual differences.

Finally, one could try to draw a parallel between the differential forms of development that we suggest and differential variables such as cognitive styles (for instance, Kogan, 1983; Witkin & Goodenough, 1981). However, save a few exceptions (e.g., Ohlmann et al, 1985; Zelniker, in press; Zelniker & Jeffrey, 1979) few authors interested in cognitive styles have jointly dealt with situational and/or developmental variations. The potential link between forms of development and cognitive style appeared plausible enough to the present authors that one task of field-dependence-independence was included in the study; analyses are still under way.

To summarize, few approaches attempted to combine developmental, experimental and differential perspectives (for a discussion, see Fischer & Silvern, 1985; Lautrey, 1984; Longeot, 1978; de Ribaupierre & Pascual-Leone, 1984). It is claimed that such an integration precisely represents an asset of the approach presented in this paper, since it attempts to describe conjointly (i.e. simultaneously and in a same language) the characteristics of both the subjects (from a developmental and differential viewpoint) and the situations.

Which cognitive developmental model for educational sciences?

Presently, no model of cognitive development appears particularly well-suited for educators, for lack of the adjunctions, modifications and transformations prerequisite to a developmental theory of instruction (e.g., Case, 1985; Rieben, Barbey, & Foglia, 1985). Obviously the program of research presented here is no exception, so much more so that it was not directed toward educational applications. However, to the extent that it challenges certain characteristics of the Piagetian model (itself frequently referred to in theories of instruction), it seems relevant to discuss some of its hypotheses and results with respect to this issue.

It was mentioned in the introduction that educators have essentially retained two postulates from the Piagetian theory, namely the constructivist postulate (children are active in the construction of their own knowledge) and the structuralist postulate (the construction of knowledge obeys to laws of totality). With respect to the first one, a constructivist model should be able to explicate the emergence of novel performances during development; the fact that the Piagetian model does not give a satisfactory account of novelty has been well documented (Bereiter, 1985; Lautrey, 1981; Pascual-Leone, 1980). Since our program of research was not intended to deal with a learning perpsective, educational implications of a constructivist perspective will not be discussed further. It appears necessary, however, to pursue further research on learning, in particular in situ and with respect to school tasks, so as to understand in depth the mechanisms underlying interactions between the students and their environments.

Inasmuch as our research program on cognitive development relies, at least in one of its phases, on a structuralism both refined and weakened, it is relevant to discuss its broad educational consequences. Educators, just like psychologists, could benefit from relying on a structuralist approach, even if it is not sufficient. Indeed, as we discussed in greater detail elsewhere (de Ribaupierre & Rieben, 1985), a structuralist approach is a prerequisite for comparisons across situations, such comparisons representing everyday tasks for teachers. Educators should also have at their disposal theoretical references on which build general hypotheses with respect to the complexity of the tasks that they suggest to their students.

A structuralist approach such as Piaget's is, however, too macroscopic and should be refined in order to adjust to the more microscopic needs of teachers. To adopt as an instructional objective in the early school years the mastery of concrete operations, represents a far too remote and almost

mythical goal, to the extent that only the teachers at the end of elementary school could evaluate whether it has been achieved. Note that this remoteness and lack of assessibility have contributed to the fact that the Piagetian educational psychology has sometime been converted into a "laisser-faire" pedagogy. Thus, any attempt to refine the description of cognitive phases, in particular in young children, is worthy. To refine the phases means to describe intermediate performances corresponding to different types of errors which teachers have to learn not to neglect, as well as imagine ways of varying the complexity of tasks.

The Piagetian structuralism is too strictly logical and formalised for being useful in many school situations. A weaker version of a structuralist approach, restricted for instance to a decomposition of tasks into "units" of treatment (such as our dimensions of transformation or Siegler's Rules), therefore less formalised and less related to logical thinking, should prove a better tool for educators. A second reason for weakening the structuralist approach originates in the necessity to take into account individual differences; when educators have to choose and analyse tasks, they essentially have to decide as to which task suggest to which student. If educators have for a long time stressed the importance of individual differences, this problematic has gained a new dimension in the context of the democratisation of schooling; nowadays, the emphasis is more often placed on the necessity for the teaching objectives, rather than for the means to reach them, to be identical for all children. The differentiation of teaching has, however, mainly consisted in adapting the rythm and not the type of teaching to students. The Piagetian structuralism, because it relies on a unidimensional model according to which individual differences only reside in the speed or rate of development, has contributed to maintain a representation of average students whose performances are uniquely characterised as a function of age. A recent trend in educational research based on Piagetian theory consists in adopting a multilinear model of development (e.g., Crahay, 1984). Differenciated teaching requires not only to size individual differences, but also to understand their nature. Attempts to classify individual differences abound, and a synthesis is often difficult (e.g., Vernon, 1984). Moreover, they are often associated with a hierarchy; for instance, field-independence is often presented as offering an advantage over field-dependence, or reflexivity over impulsivity. The approach presented here is original in that it attempts not only to account for developmental aspects, but also to describe individual differences as a

fonction of situational and behavioral characteristics; further, the two modes of processing proposed are considered equivalent with respect to their importance to the construction of knowledge. It is worth stressing that formal education consistently grants a more important role to analytical processes, or digital ones, as opposed to more intuitive or analogical modes of processing (see, for instance, Globerson, in press), with the consequence that a number of children are at a disadvantage. So does the Piagetian model. It is about time for school to rehabilitate another mode of thinking relying more heavily on mental imagery. It is not our intent to advocate for a univocal matching between types of teaching and types of students; it seems important, however, that teaching faci[illegible]s reciprocal transitions from one mode of processing to the other. In conclusion, although the distinctions suggested here seem promising, because they provide theoretical grounds for differentiated teaching, they are still highly speculative and need a good deal more empirical validation, in particular with respect to their stability (a longitudinal project is under way) before they can represent a solid contribution to education.

Authors' Notes

The research presented in this paper is the object of an international collaboration, supported by two successive grants from the Fonds National Suisse de la Recherche Scientifique (1.835-0.78, 1.440-0.81) and by the Laboratoire de Psychologie Différentielle of University of Paris V.

Authors'addresses:

Faculté de Psychologie et des Sciences de l'Education, Université de Genève. Av. General Dufour 24, 1211 Genève 4, Switzerland.

Laboratoire de Psychologie Différentielle. Université René Descartes. 41, rue Gay-Lussac, 75005 Paris, France.

Footnotes

1) Logico-mathematical operations deal with relations of resemblance or difference between discrete (discontinuous) objects, while infra-logical operations structure continuous properties and relations of proximity between parts of a same object (Piaget & Inhelder, 1947). The term "infra-logical" does not imply a lesser degree of elaboration, but refers only to a difference in scale: the object itself and its parts in the case of infra-logical operations, a set of discrete objects in the case of logico-mathematical operations. Further, these two types of operations are considered isomorphic from the standpoint of their formalisation.

2) The only empirical validation provided by Piaget to support the concept of structure d'ensemble was found in the fact that children master at approximately the same average age various notions pertaining to a same operational structure. This was plausible for the definition of a hypothetical theoretical subject, the so-called epistemic subject. However, as soon as other authors were interested in validating the properties of epistemic subjects on real subjects, and in particular, in examining the same children with a set of tasks, the correlations proved rather low. This originates in the impossibility to define structural equivalences between intermediate behaviors in different tasks. Within the Piagetian system, if an order is indeed obvious within each task, that is, if one sees clearly in a given task why level IIB follows level IIA, while preceding level IIIA, the theory provides no explicit structural ground for an equivalence between level IIA in one task and level IIA in another.

3) This term is used by analogy with body joints; we could have used the term of coordination, but it refers too precisely to the way in which Piaget conceptualised the subjects' activities and the relationships between elements.

4) For instance, according to the analysis presented in Figure 2, Item 2 of Folding of Lines requires articulation of the three dimensions of transformation, and constitutes therefore a relatively difficult item. It is possible, however, that the three dimensions need not be taken into account simultaneously: subjects could in a first step focus in a rather global manner on the lower part, representing it as an inverse V; this part would be rotated all in once (instead of element by element), resulting in a V with its basis on the fold (articulation of the first two dimensions); finally, subjects would decide, by resorting to the left-right dimension, on the color of each branch. This strategy is facilitated by the Gestalt-like aspect of this item; it requires at most

the simultaneous articulation of two dimensions, thus presenting a lesser degree of complexity, which is more congruent with the results obtained. 5) The greater difficulty of application of a digital mode to continuous situations corresponds to the type of decalage that Piaget mentioned as more likely between logico-mathematical and infra-logical tasks. Indeed, although he considered both types of operations to be isomorphic (see Note 1), he nevertheless mentioned the possibility of decalage in their acquisition (e.g., Piaget & Inhelder, 1947; Lautrey et al, 1985), for the following reasons. First, the elements within the "infra-logical whole" are inter-dependent and meaningful configurations have to be broken down before relationships between the parts can be brought out; by contrast, in the logico-mathematical domain, configurations are neither relevant nor stable. Second, infra-logical operations deal with continuous properties, and require introduction of arbitrary partitioning, while elements dealt with by logico-mathematical operations are already isolated.

This is a reason to think that Piaget favored a digital mode of processing over an analogical mode. A second reason to see this dissymetry in Piaget's model originates in the related distinction introduced between figurative and operative aspects of knowledge (e.g., Piaget & Inhelder, 1966). Operative aspects deal with transformations, whereas figurative aspects, that is, perception, imitation and mental imagery, are defined as dealing only with states and their evolution is considered to be subordinated to that of operative aspects. By contrast, the equivalence posited here between digital and analogical modes of processing implies that figurative aspects of knowledge are much more autonomous and contribute also to monitor the construction of knowledge.

References

Anderson, J.R. (1983). The architecture of cognition. Cambridge, Mass: Harvard University Press.

Benzecri, J.P. (1973). L'analyse des données. Paris: Dunod.

Bereiter, C. (1985). Toward a solution of the learning paradox. Review of Educational Research, 55, 201-226.

Brainerd, C. J. (1978). The stage question in cognitive-developmental theory. The Behavioral and Brain Sciences, 2, 173-182.

Brown, A.L., Bransford, J., Ferrara, R.A., & Campione, J.C. (1983). Learning, remembering and understanding. In P.H. Mussen (Ed). Handbook of child psychology, Vol.3. New York: Wiley, 77-166.

Bruner, J.S. (1964). The course of cognitive growth. American Psychologist, 19, 1-15.

Bruner, J.S., Greenfield, P.M., & Olver, R.R. (1966). Studies in cognitive growth. New York: Wiley.

Case, R. (1978). Intellectual development from birth to adulthood: A neo-Piagetian interpretation. In R. Siegler (Ed). Children's thinking: What develops? Hillsdale, N.J.: Erlbaum, 37-72.

Case, R. (1985). Intellectual development: Birth to adulthood. New York: Academic Press.

Case, R., Marini, Z., McKeough, A., Dennis, S., & Goldberg, J. (1986). Horizontal structure in middle childhood: Cross-domain parallels in the course of cognitive growth. In I. Levin (Ed). Stage and structure. Reopening the debate. Norwood, N.J.: Ablex, 1-39.

Crahay, M. (1984). Observer et réguler la construction des actions avec les objets. Essai d'exploration théorique et expérimentale de la transposition du constructivisme à l'éducation préscolaire. Unpublished doctoral dissertation, Université de Liège.

Denis, M. (1979). Les images mentales. Paris: PUF.

Dodwell, P.C. (1960). Children's understanding of number related concepts. Canadian Journal of Psychology, 14, 191-205.

Fischer, K.W. (1980). A theory of cognitive development: The control and construction of hierarchies of skills. Psychological Review, 87, 477-531.

Fischer, K.W., & Silvern, L. (1985). Stages and individual differences in cognitive development. Annual Review of Psychology, 36, 613-648.

Froman, T., & Hubert, L.J. (1980). Application of prediction analysis to developmental priority. Psychological Bulletin, 87, 136-146.

Galifret-Granjon, N. (1981). Naissance et évolution de la représentation chez l'enfant. Paris: PUF.

Globerson, T. (in press). What is the relationship between cognitive style and cognitive development? To appear in T. Globerson & T. Zelniker (Eds). Cognitive development and cognitive style. Norwood, N.J. Ablex.

Hildebrand, D.K., Laing, J.D., & Rosenthal, H. (1977). Prediction analysis of cross-classifications. New York: John Wiley.

Kemler, D.G., & Smith, J.D. (1978). Is there a developmental trend from integrality to separability in perception? Journal of Experimental Child Psychology, 26, 498-507.

Kemler Nelson, D.G., & Smith, J.D. (in press). Holistic and analytic processing in reflexion-impulsivity and cognitive development. To appear in T. Globerson & T. Zelniker (Eds). Cognitive development and cognitive style. Norwood, N.J. Ablex.

Kogan, N. (1983). Stylistic variation in childhood and adolescence. In P.H. Mussen (Ed). Handbook of child psychology, Vol.3. New York: Wiley, 630-706.

Lautrey, J. (1981). L'équilibration suffit-elle à guider les actions? Psychologie Française, 24, 259-272.

Lautrey, J. (1984). Diversité comportementale et développement cognitif.

Psychologie Française, 29, 16-22.
Lautrey, J., de Ribaupierre, A., & Rieben, L. (1985). Intra-individual variability in the development of concrete operations: Relations between logical and infralogical operations. Genetic, Social and General Psychology Monographs, 111, 167-192.
Lautrey, J., de Ribaupierre, A., & Rieben, L. (1987). Operational development and individual differences. In E. De Corte, J.G.L.C. Lodewiks, R. Parmentier, & P. Span (Eds). Learning and Instruction. Oxford/Leuven: Pergamon Press/ Leuven University Press.
Lautrey, J., de Ribaupierre, A., & Rieben, L. (1986). Les différences dans la forme du développement cognitif évalué avec des épreuves piagétiennes: une application de l'analyse des correspondances. Cahiers de Psychologie Cognitive, 6, 575-613.
Longeot, F. (1969). Psychologie différentielle et théorie opératoire de l'intelligence. Paris: Dunod.
Longeot, F. (1978). Les stades opératoires de Piaget et les facteurs de l'intelligence. Grenoble: Presses Universitaires de Grenoble.
Lunzer, E. (1960). Some points of Piagetian theory in the light of experimental criticism. Journal of Child Psychology and Psychiatry, 1, 191-202.
Neimark, E. (1981). Confounding with cognitive style factors: An artifact for the apparent non-universal incidence of formal operations. In I. Sigel, R. Golinkoff, & D. Brodzinski (Eds).New directions in Piagetian theory and practice. Hillsdale, N.J. Erlbaum, pp.177-189.
Ohlmann, T. (1985). Variabilité intra-individuelle et dépendance-indépendance à l'égard du champ visuel. In J. Drevillon, M. Huteau, F. Longeot, M. Moscato, & T. Ohlmann (Eds). Fonctionnement cognitif et individualité. Bruxelles: Mardaga, 185-230.
Ohlmann, T., Bejean, M., Bouscarel, M., Cian, C., Dubourdeau, G., Mourier, G., Muzet, E., & Verchere, M. (1985). Horizontale et verticale posturales ou horizontale et verticale opératoires? Cahiers de Psychologie Cognitive, 5, 707-726.
Paivio, A. (1971). Imagery and verbal processes. New York: Holt, Rinehart & Winston.
Pascual-Leone, J. (1976). A view of cognition from a formalist's perspective. In K.F. Riegel, & J.A. Meacham (Eds). The developing individual in a changing world. Vol. 1. The Hague: Mouton, pp. 89-100.
Pascual-Leone, J. (1980). Constructive problems for constructive theories: The current relevance of Piaget's work and a critique of information-processing simulation psychology. In R. Kluwe & H. Spada (Eds). Developmental models of thinking. New York: Academic Press, pp. 263-296.
Piaget, J. (1968). Introduction. In M. Laurendeau, & A. Pinard. Les premières notions spatiales de l'enfant. Neuchâtel: Delachaux & Niestlé, 5-10.
Piaget, J. (1976). Le possible, l'impossible et le nécessaire. Archives de Psychologie, 44 (172), 281-299.
Piaget, J., & Inhelder, B. (1947). La représentation de l'espace chez l'enfant. Paris: PUF.
Piaget, J., & Inhelder, B. (1966). L'image mentale chez l'enfant. Paris: PUF.
Reuchlin, M. (1978). Processus vicariants et différences individuelles. Journal de Psychologie, 2, 133-145.
de Ribaupierre, A. (1975). Mental space and formal operations. Unpublished doctoral dissertation, University of Toronto (University Microfilms International, 7819278).
de Ribaupierre, A. (in press). Operational development and cognitive style: A review of french literature and a neo-Piagetian reinterpretation. In T. Globerson & T. Zelniker (Eds). Cognitive development and cognitive style. Norwood, N.J.: Ablex.
de Ribaupierre, A., & Pascual-Leone, J. (1984). Pour une intégration des

méthodes en psychologie: approches expérimentale, psycho-génétique et différentielle. L'Année Psychologique, 84, 227-250.

de Ribaupierre, A., Rieben, L., & Lautrey, J. (1985). Horizontal decalages and individual differences in the development of concrete operations. In V. Shulman, L. Restaino-Baumann, & L. Butler (Eds). The future of Piagetian theory: The neo-Piagetians. New York: Plenum, 175-197.

de Ribaupierre, A., & Rieben, L. (1985). Etude du fonctionnement opératoire: quelques problèmes méthodologiques. Bulletin de Psychologie, 38 (372), 841-852.

Rieben, L., Barbey, C., & Fogiia, D. (1985). Différenciation de l'enseignement et apprentissage de la langue écrite. Education et Recherche, 7, 29-50. (Erratum, 1986, 8, 136).

Rieben, L., de Ribaupierre, A., & Lautrey, J. (1983). Le développement opératoire chez l'enfant de 6 à 12 ans. Elaboration d'un instrument d'évaluation. Paris: Editions du CNRS.

Rieben, L., de Ribaupierre, A., & Lautrey, J. (1986). Une définition structuraliste des formes du développement cognitif: un projet chimérique? Archives de Psychologie.

Shepard, R.N., & Cooper, L.A. (1982). Mental images and their transformations. Cambridge, Mass.: The MIT Press.

Siegler, R.S. (1981). Developmental sequences within and between concepts. Monographs of the Society for Research in Child Development, serial no 189.

Siegler, R.S. (1983). Information-processing approaches to development. In P.H. Mussen (Ed). Handbook of child psychology, Vol.3. New York: Wiley, 129-211.

Siegler, R.S. (1984). Mechanisms of cognitive growth: Variation and selection. In R.J. Sternberg (Ed). Mechanisms of cognitive development. New York: Freeman, 142-162.

Siegler, R.S., & Klahr, D. (1982). When do children learn: The relationship between existing knowledge and the ability to acquire new knowledge. In R. Glaser (Ed). Advances in instructional psychology, Vol.2. Hillsdale, N.J.: Erlbaum, pp.121-211.

Snow, R.E., & Yalow, E. (1982). Education and intelligence. In R.J. Sternberg (Ed). Handbook of human intelligence. Cambridge, Mass: Cambridge University Press, 493-585.

Sternberg, R.J. (1980). Sketch of a componential subtheory of human intelligence. The Behavioral and Brain Sciences, 3, 573-614.

Sternberg, R.J. (1983). Components of human intelligence. Cognition, 15, 1-48.

Tuddenham, R.D. (1971). Theoretical regularities and individual idiosyncrasies. In D.R. Green, M.P. Ford, & G.B. Flamer (Eds). Measurement and Piaget. New York: McGraw Hill, pp. 64-80.

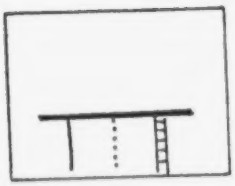
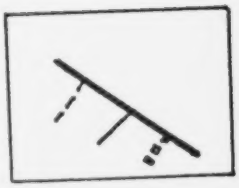
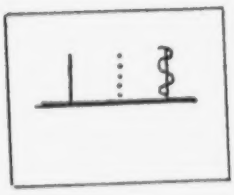
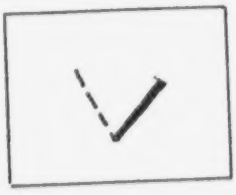
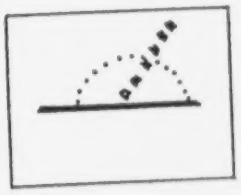
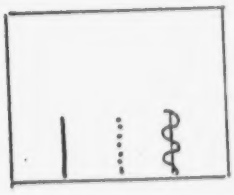
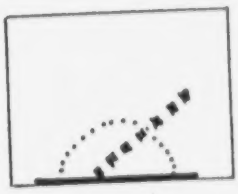
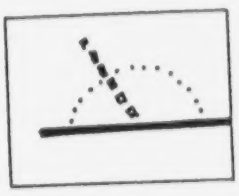
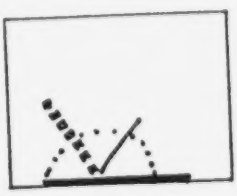
Vernon, P.E. (1984). Intelligence, cognitive style nd brain lateralization. International Journal of Psychology, 19, 435-455.

Witkin, H.A., & Goodenough, D.R. (1981). Cognitive styles: essence and origins. New York: International Universities Press.

Zelniker, T. (in press). Cognitive style and dimensions of information-processing. To appear in T. Globerson & T. Zelniker (Eds). Cognitive development and cognitive style. Norwood, N.J. Ablex.

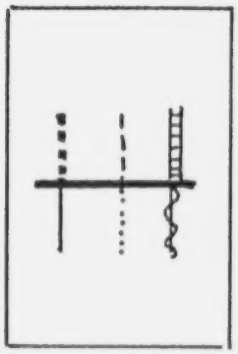
Zelniker, T., & Jeffrey, W.E. (1979). Attention and cognitive style in children. In G.A. Hale & M. Lewis (Eds). Attention and cognitive development. New York: Plenum, pp. 275-296.

Items

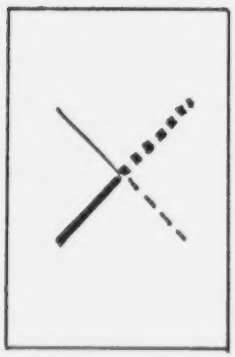
	1	2	3	4
1	«Copy». See unfolded items			
2				
3				
4				
5				
6				

Unfolded

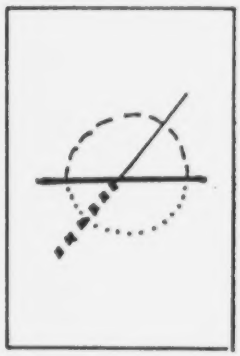
Item 1



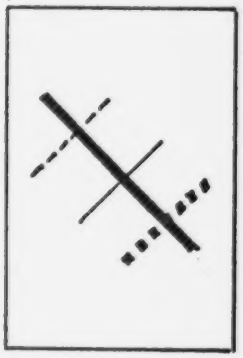
Item 2



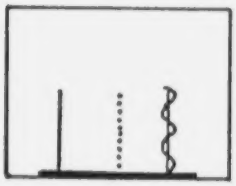
Item 3

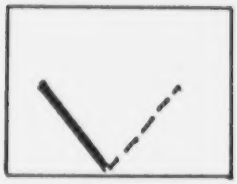


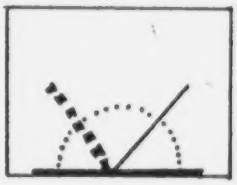
Item 4

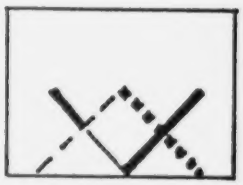


Folded









Legend

red

black

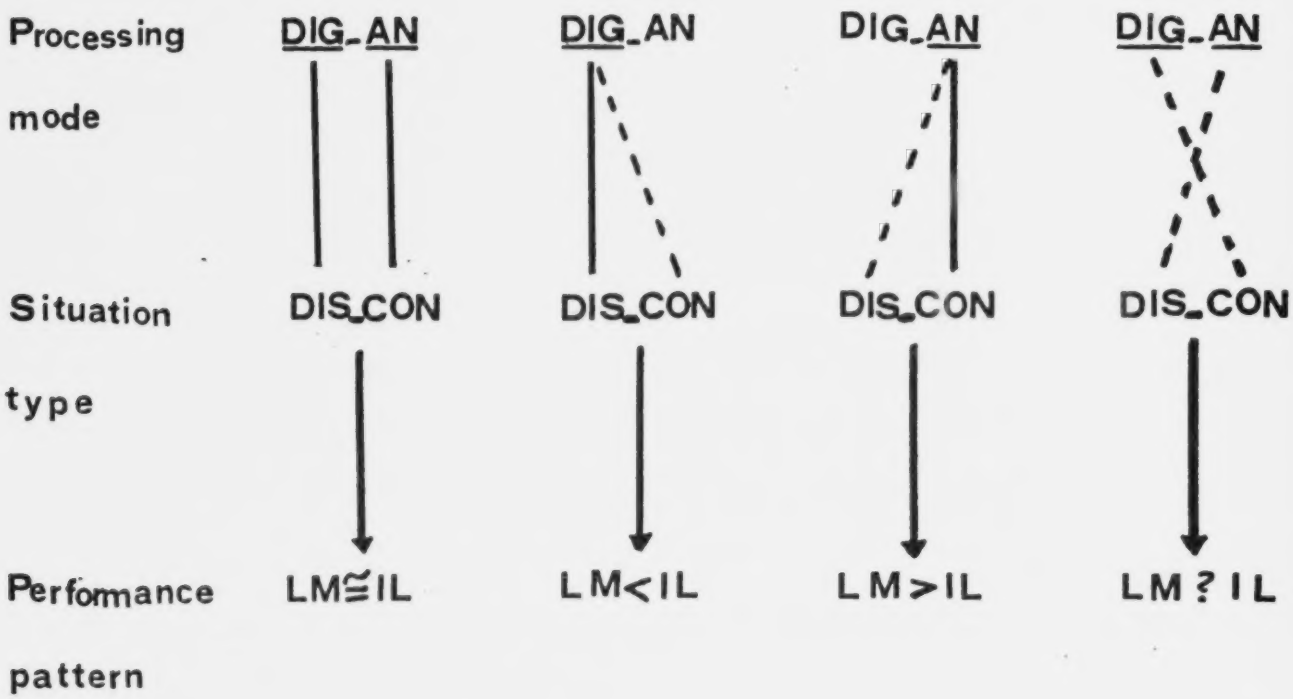
blue

purple

yellow

green

brown



DIG	digital	DIS	discrete
AN	analogical	CON	continuous
LM	logico-math.	<	easier than
IL	infra_logical	>	more difficult than